

Geomatics at the End of the Century: Framing a New Agenda

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Summary

It is a very special pleasure to have been invited to make a presentation to the Cambridge Conference. The objectives of this presentation will be to:

- briefly reflect on what has been accomplished in terms of 'mapping the world' as we come to the end of the twentieth century;
- examine the growing interest in the geospatial data infrastructure concept and its current state of development; and
- briefly look beyond building the infrastructure to the next agenda (in this case picking up on two themes: living in the virtual world; the new age of exploration).

The following sections set out a framework and provide some background documentation for the presentation.

Background

Since the days of Prince Henry the Navigator – and particularly during the periods of exploration and colonisation which followed – a 'Maslow' like hierarchy has defined the agenda of surveying and mapping efforts at the local, national and transnational levels. Early initiatives supporting: (i) defence and public safety have over time given way to those supporting (ii) settlement, resource development and public infrastructure. Arguably, these two stages characterised the mapping world until the end of World War II. Since that time, mapping programmes within and between different countries have refocused their efforts and moved through two less well-defined (and often overlapping) stages supporting (iii) commercial applications; and (iv) a broader societal agenda (including environmental monitoring). As well, while cartography per se has a long and complex history, the challenges associated with the planning and production of detailed, systematic mapping on a jurisdiction wide basis have been primarily tackled only in this century.

National mapping efforts

Of course European organisations such as the Ordnance Survey have a much longer tradition spanning hundreds of years. As well, from the 1700s through early 1900s, there are numerous examples of early systematic surveys in support of exploration and trade, including:

- The Lewis and Clark expedition opening up the American West.
- In Australia, Mitchell's 1834 *Map of the 19 Counties* and the triangulation surveys of the 1830s.
- The extensive advance surveys and mapping work carried out in support of transcontinental railway construction in the mid 1800s in Canada.

In a sense, Sir Ernest Shackleton's legendary Antarctic expedition carried out at the height of World War I – the Imperial Trans-Antarctic Expedition – represented a milestone which brought the age of exploration to an end. After a comparative lull in activity through the 1920s and 1930s, the commitment to systematic surveying and mapping efforts began in earnest after World War II. Summaries of a number of systematic national mapping programmes may be found in (Rhind, 1997), and discussions of post-war national efforts in Australia and Canada may be found in (Larsgaard, 1984) and (McGrath and Seibert, 1999) respectively.

Despite all this, traditional sources like Brandenberger and more recent inventories of national mapping efforts confirm that only limited mapping coverage is available in many developing countries. Further, while we often quip that more is known about the backside of the moon than the bottom of the ocean, the sad reality is that it's true. The best global scale images of the seafloor, based on satellite-derived gravity data, can resolve features no smaller than approximately 15 km in wavelength. In contrast, the Mariner images of Mercury resolved features down to 1.5 km and the Clementine mission to the moon mapped the entire surface of the moon to a resolution of about 150 m. We now have the means to generate spectacularly high-resolution images of the seafloor but, to date, these systems have mapped only a very small percentage of the ocean floor.

Global mapping initiatives

A brief history

Resolutions and recommendations related to the goal of global mapping have been repeatedly adopted at many international conferences, beginning more than a century ago. See (ISCGM, 1998b). For example:

1891: The Bern Assembly of the International Geographic Congress opened a new era by adopting a resolution to provide uniform mapping of the world at a scale of 1:1 000 000 based on common specifications. Out of this resolution grew the International Map of the World (IMW) project.

1953: The United Nations Economic and Social Council adopted a resolution to provide maps based on common world specifications with a scale of 1:1 000 000.

1955: The first meeting of the United Nations Regional Cartographic Conference for Asia and Far East adopted a resolution to develop more maps based on common world specifications with a scale of 1:1 000 000.

1987: A joint project group formed by the International Geographical Union and the International Cartographers Association (ICA) proposed the world digital data base for environmental sciences project.

1992: Publication of the Digital Chart of the World (DCW). It is a 1:1 000 000 scale map based on digitisation of the ONC. DCW was a cooperative effort by organisations in Australia, Canada, the United Kingdom and the United States of America.

1994: The International Symposium on Core Data Needs for Environmental Assessment and Sustainable Development Strategies held by the UNEP and UNDP in Bangkok, Thailand. It was concluded that top priority should be placed on the provision of data on the following 10 items in order to encourage sustainable development: (a) land use/land cover, (b) population, (c) hydrology, (d) public facilities, (e) climate, (f) topography, (g) economics, (h) soil, (i) atmospheric pollution and (j) water quality.

1995: At an international conference concerning the establishment of the Permanent Committee on GIS Infrastructure for Asia and the Pacific held in Kuala Lumpur, Malaysia, it was announced that the goal of the permanent committee's activities would be to build a global geographic information system by forming regional geographic information systems in order to contribute to environmental protection and to economic and social development in line with the goals of Agenda 21.

1996: At the meeting of the executive board of the Permanent Committee on GIS Infrastructure for Asia and the Pacific held in Kuala Lumpur, rules of procedure and operational status were adopted. However, it was also recognised that the priority of many developing countries was still to complete their unfinished national mapping programmes.

Despite the programmes summarised above, much of what is known about the Earth's surface still remains inaccessible: billions of dollars have been spent collecting data sets that, for reasons of national security or other reasons, remain tightly restricted. Even the data that is available are, in many cases, so poorly organised or incompatible with other data sets that they are effectively useless.

The global mapping project

Developed partly in response to such frustration, the Global Mapping Project concept was advocated by the Ministry of Construction of Japan as a response to the United Nations Conference on Environment and Development held in Brazil in 1992 (AUSLIG, 1999). The objective of the project is to bring together all nations and concerned organisations to develop and provide easy and open access to global digital geographic information at a scale of 1:1 000 000.

To this end, the Geographical Survey Institute of Japan (GSI) proposed the first draft Map Specifications in 1994. Further, the International Steering Committee for Global Mapping (ISCGM) was established in February, 1996 in Tsukuba, Japan, to provide a forum and to examine measures that concerned national, regional and international organisations could take to foster the development of Global Mapping (ISCGM Home Page, 1996).

Over the past five years and through more than a half-dozen meetings, the ISCGM has worked with a number of official, formal and informal organisations in promoting the role of global mapping in general – and their efforts in particular – in the development and support of global spatial data infrastructure (ISCGM, 1998).

Global mapping data sets and data collection initiatives

As with their local and national counterparts, global mapping efforts wax and wane through cyclic periods of new collection, sporadic updating, and aggregation of existing data into new data sets. While much more detailed systematic coverage is still clearly needed today, significant data already exists on a global scale. For example:

- Global 30 Arc Second Elevation Data Set (GTOPO30) (US Geol. Survey, EROS Data Centre): Elevation (DEM).
- Global Land Cover Characteristics Database (US Geol. Survey, U. of Nebraska-Lincoln, EC Joint Research Centre): Land cover, Land use and Vegetation.
- VMAP Level 0 (NIMA): Drainage System (rivers, streams, lakes), Transportation (roads, railways, airports), Political Boundaries (including coastlines), Populated Places.

A more detailed list summarising global and regional mapping initiatives is contained in Table 1.

A number of other more recent public and private initiatives promise to provide richer and more comprehensive imagery and terrain data coverage worldwide over the next three years. Table 2 outlines the details of recent or forthcoming high-resolution remote sensing missions.

In addition to these efforts, the objective of Shuttle Radar Topography Mission (SRTM) – an international project spearheaded by the U.S. National Imagery and Mapping Agency (NIMA) and the National Aeronautics and Space Administration (NASA) – is to obtain the most complete high-resolution digital topographic database of the Earth. According to NIMA/NASA sources, this radar system will gather data that will result in the most accurate and complete topographic map of the Earth's surface that has ever been assembled. (NASA/NIMA, 1999).

As an aside, we note that the capability of this next generation of sensors has not escaped the attention of legislators and those tasked with maintaining national security in their own countries. Recent lobbying by Israel to ban the sale of satellite images of its defensive positions (Steinberg, 1998), and the recent refusal of NASA to launch Canada's high-resolution Radarsat II because it might 'compromise U.S. national security' are good examples of early responses to the potential invasive power of these new satellites. Both reactions point to a growing realisation (and perhaps justifiable paranoia) that this technology comes with 'baggage' related to national, industrial and personal security, to say nothing of the longer-term impact on both internal and international regulatory, environmental and trade practices.

New initiatives not only deal with the collection of mapping data sets. Clearly, clearing-house efforts like Canada's CEONet, Australia's ERIN and the American FGDC will enable users to locate data of interest much more quickly than before. Often operating at a level of capacity, an order of magnitude higher than more regional providers, emerging commercially sponsored sites like Microsoft's Terraserver, the GIS Data Depot and others are just beginning to represent the next generation of data distributors. Unlike their predecessors who tended to deal with relatively 'focussed' collections of base mapping series and theme overlays, rapidly advancing spatial data warehousing technology will enable these 'virtual box stores' to have the potential to eventually handle distribution of spatial data at the local, national, transnational and even global levels.

From systematic national mapping to spatial data infrastructure

Over the past thirty years, we have seen the driving ideals and institutional responses arising from the integrated mapping ideals of the 1960s, the multipurpose cadastre concept and land information databanks of the 1970s, the prescient (but premature) land information network visions of the 1980s, and the early ideals of geographic information infrastructure. Until the early 1990s, technological limitations and long, expensive database loading programmes limited the number of jurisdiction-wide, multi-participant land information projects that would qualify as 'geospatial data infrastructure'. However, a number of strategic factors have combined over the past decade to accelerate the interest and levels of user expectation. Some of these factors – discussed at length in Coleman and McLaughlin (1998) include:

- The increasing prominence of spatial data handling and management within organisations.
- Availability of robust, easy to use and relatively inexpensive desktop software tools for spatial data viewing, modelling and analysis.
- Requisite digital spatial data sets covering **entire** areas of interest now becoming more accessible, widely available and better packaged than ever before.
- A large and increasing number of specialists and informed end users are now familiar with the capabilities and limitations of both the tools and data sets **and** with how they relate to the requirements of their particular business.
- The ubiquitous and inexpensive positioning, tracking and navigation capabilities of GPS are already pushing the next wave of market developments and having an effect on the manner in which end users view and employ existing spatial data sets.
- The widespread reach and increasing performance of voice and data communications networks worldwide.
- A critical mass of organisations and individuals which have now worked through the technical and cultural transformations inherent in providing employees with desktop access to corporate networks and, more recently, the internet.

By the early 1990s, the concept of spatial data infrastructure (SDI) development was being proposed in support of accelerating geographic information exchange standards efforts, selected national mapping programmes and the establishment of nationwide spatial information networks. Beginning in Canada (McLaughlin, 1991), the idea was picked up and aggressively advanced by the Americans (Mapping Sciences Committee, 1993), the United Kingdom (Rhind, 1992) and the European Community (EUROGI, 1996). Recent work by Masser (1998) and Onsrud (1998) have catalogued spatial data infrastructure efforts now underway in over twenty-five countries worldwide.

Interest in extending these national efforts to the global level has been evident in several different communities, including:

- The defence community (Lenczowski, 1995).
- The International Hydrographic Organisation.
- Again, the work of the ISCGM.
- National and regional mapping organisations, as evidenced through the Conferences on Emerging Global Spatial Data Infrastructure held in Bonn, Germany in September, 1996, Raleigh, U.S.A. in October, 1997, and Canberra, Australia in November, 1998 (EUROGI, 1999).

Inspired by efforts which began (at least under this umbrella) in the United States, most of these spatial data infrastructure efforts have been characterised by their focus on the following:

- promoting policies and partnerships which facilitate spatial data integration and sharing (especially, at least in the beginning, among federal government departments);
- supporting inclusive efforts to identify and formally recognise foundation data and framework data sets; and
- promoting the establishment and growth of spatial data clearing houses and metadata standards.

As discussed in Coleman (1999) and elsewhere, such focus on these particular efforts promotes the idea of the spatial data infrastructure as purely an 'on-line map library', which may prove to be too limiting in the longer term. All the same, while this may indeed be a 'lesser vision' of SDI, it is still probably a more appropriate one for most of the world at this time given the continued requirements for comprehensive, high-quality mapping coverage. This being the case – and given the helping hand of the world wide web – it should be no surprise that American FGDC-inspired initiatives and specifications have become de facto standards internationally.

Current challenges

Expanding the already problematic objectives of national and global mapping efforts into the creation of spatial data infrastructures poses a challenging series of institutional, operational and technical problems on a number of levels. A number of the non-technical ones already identified are included here in outline form and will be discussed further in the presentation:

- 'Horizontal' data sharing issues – examining the respective roles of public sector organisations at the same level of government.
- 'Vertical' data sharing issues – examining the respective roles of different levels of public sector organisations in providing, maintaining and applying spatial data.
- Effect of the 'Internet Model' on SDI – growing concerns over perceived American domination of key technologies associated with both the collection, discovery and on-line dissemination of spatial data.
- Evolving models of financing the maintenance and on-line dissemination of spatial information products and transactions.
- Avoiding the prospect of information 'haves' and 'have-nots' between developed and developing countries.

Beyond infrastructure: towards virtual communities and the new age of exploration

The steps beyond the implementation stages of spatial data infrastructure will prove as exciting and challenging to the next generation of producers, users and researchers as it will be, perhaps, foreign and confusing to this one. Technological predictions regarding 'personal location and navigation appliances'; real-time, web-based electronic atlases and travel guides; and others are already realised in prototype form.

In the longer term, the convergence of groupware and GIS technologies promises to empower a new generation of citizens interested in challenging existing approaches to urban planning and community development. Through the use of synchronous or non-synchronous discussions and on-line 'collaboratories', citizens will be able to review existing proposals, potentially model the implications of these developments, and then suggest – and test – the characteristics and impact of proposed alternatives. Examples of early efforts at applying these technologies to collaborative decision making and 'Public Participation GIS' may be found in Faber et al. (1994) and (1998), NCGIA (1995), Klein (1998) and NCGIA (1998). In the presentation we will discuss one such effort – the 'Delta Project' – just beginning to take shape in the Canadian province of New Brunswick.

As we approach the next millennium, we find nations working at all stages of the hierarchy mentioned at the beginning of this paper:

- developing countries are still very much involved in mapping to support settlement, resource development and public infrastructure;
- at the national levels in North America, the United Kingdom and Australia, and at the state and local levels in countries around the world, in support of commercial applications;
- mapping in support of a variety of social and environmental objectives are exemplified at the project level (and, to a lesser extent, the programme level) around the world; and
- finally, while most mapping in support of earth – or, at least, 'dry land' – exploration has been completed, exciting new initiatives in terms of ocean mapping and space exploration are pushing mankind into a 'second-generation' hierarchy of initiatives.

The information that can be derived from new ocean mapping systems is tremendous, both in quantity and content – combined with the proper processing and visualisation techniques they can, in essence, make the ocean transparent and provide aerial photograph like coverage of the seafloor (UNB Ocean Mapping Group, 1999). Given the irrefutable importance of the ocean's to our physical, spiritual and economic well-being, the challenge facing us will be to find the means to collect and properly analyse and manage the vast amounts of data yet to be obtained from the uncharted regions of our ocean's floor.

The same can be said of mapping in support of space exploration. In space, over fifteen missions to the moon and planets within our solar system are now underway or in the planning stages. Satellite imagery and sensor data now available has given mankind an infinitely more detailed view of the surfaces of most planets within our solar system than the early explorers had of the world beyond Europe and the Middle East (ISPRS, 1999). The real limitations will be on our ability to process, interpret and – as Goethe said – '**understand** the vast amounts of data at our disposal'.

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Table 1**Examples of global or transnational mapping efforts currently underway**

Project title and originator	Theme	Progress	Source description
<p>AFRICOVER UN Food and Agriculture Organisation (FAO) In conjunction with Italian government, French cooperation, European Union, GTZ, CIDA, World Bank</p>	<p>Land cover and a geographic referential (geodesy, toponymy, roads, hydrography)</p>	<p>FAO has started the implementation of three international working groups to prepare the technical specifications of the project, for land cover, legend and classification, geometry and topography, and technical methods</p> <p>The East-African sub-region (11 countries of the Nile basin) started execution of the project in 1996</p>	<p>High-resolution satellite images</p> <p>Existing topographic maps and updated from remote sensing documents and ground surveys geo-referenced from GPS points</p>
<p>CORINE Commission of the European Communities In conjunction with National Land Cover teams of individual European countries</p>	<p>Computerised inventory of Europe's land cover</p>	<p>Complete: Belgium, Czech, Ireland, Luxembourg, Netherlands, Portugal, Spain</p> <p>Partially Compete: Austria, Bulgaria, France, Germany, Greece, Hungary, Italy, Norway, Romania, Slovakia, Poland</p> <p>Under preparation: Albania, Denmark, Estonia, Finland, Latvia, Lithuania, Slovenia, Sweden, United Kingdom</p>	<p>Landsat MSS, TM and SPOT HRV</p>
<p>Digital Chart of the World (DCW) edition 2 U. S. National Imagery and Mapping Agency (NIMA) (formerly U. S. Defense Mapping Agency (DMA) In conjunction with Military mapping organisations in Australia, Canada and the UK</p>	<p>Map (roads, rail networks, rivers, lakes, steams, major utility networks, cross-country pipelines, communication lines, airports, elevation, contours, coastlines, international boundaries, populated places, geographic names)</p>	<p>Complete in 1991</p> <p>Revised in 1995</p>	<p>Operational Navigation Charts (ONCs) and Jet Navigation Charts (JNCs). JNCs were used as source for the Antarctica region only. Source maps were revised is from 1974 to 1991</p>

<p>Global 30 Arc-second Elevation Data (GTOPO30)</p> <p>U.S. Geological Survey, EROS Data Center</p> <p>In conjunction with</p> <p>USGS, NASA, UNEP/GRID, USAID, DMA, the Instituto Nacional de Estadística Geográfica e Informática (INEGI) of Mexico, the Geographical Survey Institute of Japan, the Antarctic Digital Database, and the New Zealand Manaaki Whenua Landcare Research Agency</p>	<p>Elevation</p>	<p>Version 1.0 of the global data set now available</p>	<p>Compiled from various data sources, including the 1:1 000 000 scale Digital Chart of the World (DCW)</p>
<p>Global Land Cover Characterisation and DIS Land Cover data set (DISCOVER)</p> <p>Project coordinated by IGBP-DIS LCWG and VWG. Originated by the U.S. Geological Survey, EROS Data Center</p> <p>With funding provided by the USGS, NASA, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Forest Service, and the United Nations Environment Programme</p>	<p>Land Cover</p>	<p>The final phase of the global classification and validation completed in 1998</p>	<p>One-kilometer AVHRR NDVI composites are the core data set used in land cover characterisation in addition to other key geographic data</p>
<p>Global Land One-kilometer Base Elevation (GLOBE) digital elevation model</p> <p>Ad-hoc GLOBE Project Team National Oceanic and Atmospheric Administration (Secretary)</p> <p>DLR German Aerospace Research Establishment</p> <p>University College London</p> <p>U. S. Geological Survey</p> <p>U. S. Defense Mapping Agency Geographical Survey Institute (Japan)</p> <p>Australian Surveying and Land Information Group.</p>	<p>Elevation</p>	<p>Most major pieces of global coverage have been assembled. Several enhancements are still underway.</p>	<p>Compiled from various data sources, including:</p> <p>U. S. Defense Mapping Agency Digital Terrain Elevation Data (DTED).</p> <p>1:1,000,000 scale Digital Chart of the World (DCW) mapping; and</p> <p>The Australian Surveying and Land Information Group's high-resolution point elevation data set.</p>

Table 2

Sources of high-resolution imagery

Source: Federation of American Scientists (1999). <http://www.fas.org/eye/sources.htm>, updated Monday, February 15, 1999.

	Space imaging	Orbimage	Earthwatch		West Indian space		Other
Spacecraft	IKONOS	Orbview	EarlyBird	QuickBird	EROS-A	EROS-B	KVR-1000
Launch date	Jun 1999	1999	Dec 1997 failed	late 1999	late 1999	1999	current
Swath width (1-meter panchromatic)	11 km	8 km		27 km		20 km	
Swath 2-meter panchromatic		8 km			14 km		2 km 10 km 40 km
Swath width (3-meter panchromatic)			3 km				
Swath width (4-meter multispectral)	? km	8 km		27 km			
Revisit interval	2-4 days	3 days	?	?	3	1	?
Cost/scene	\$250 (USA) \$6,500 (world)		\$300 3x3 km				\$30 1x1 km \$300 2x2 km \$300 4x4 km \$4000 10x10 km